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(58) Field of Search

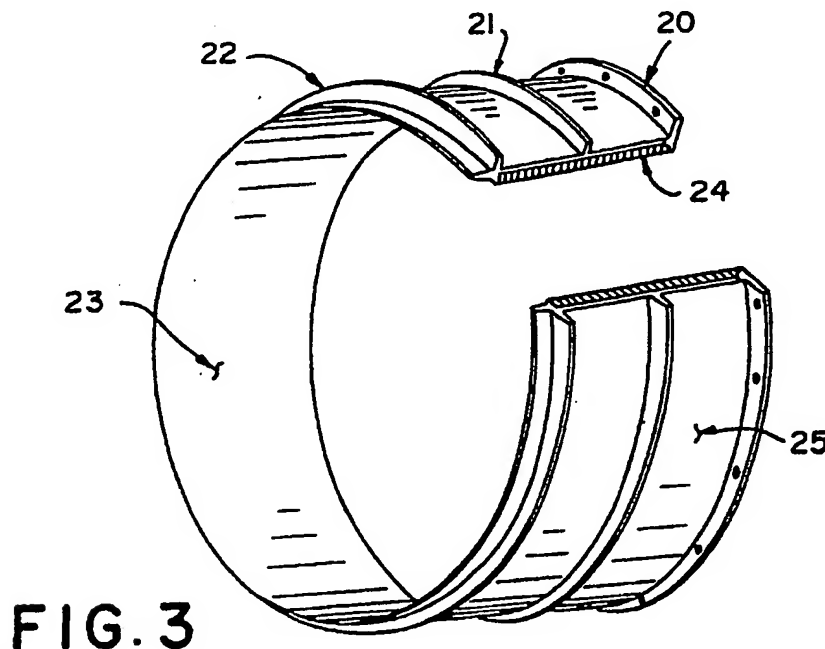
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INT CL⁵ F02C 7/00 7/04 7/045

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(54) Engine inlet acoustic barrel

(57) An acoustic liner jet engine inlet barrel is formed from a perforated permeable skin 23, a honeycomb core 24, and a solid facesheet 25, each of which is formed in a one-piece configuration such that at most only a narrow single for-to-aft splice (19), (fig 2(a)) or no splice at all, is present in the finished product. The acoustic modal content remains unaffected, thus preserving a high degree of liner effectiveness, increasing the total active acoustic area of the barrel while decreasing its weight, and increasing its durability. Engine mounting flanges and a firewall ring frame attachment flange, 20, 21, 22, may be formed integrally with the facesheet 25. The facesheets may be formed by wrapping graphite/epoxy cloth prior to curing



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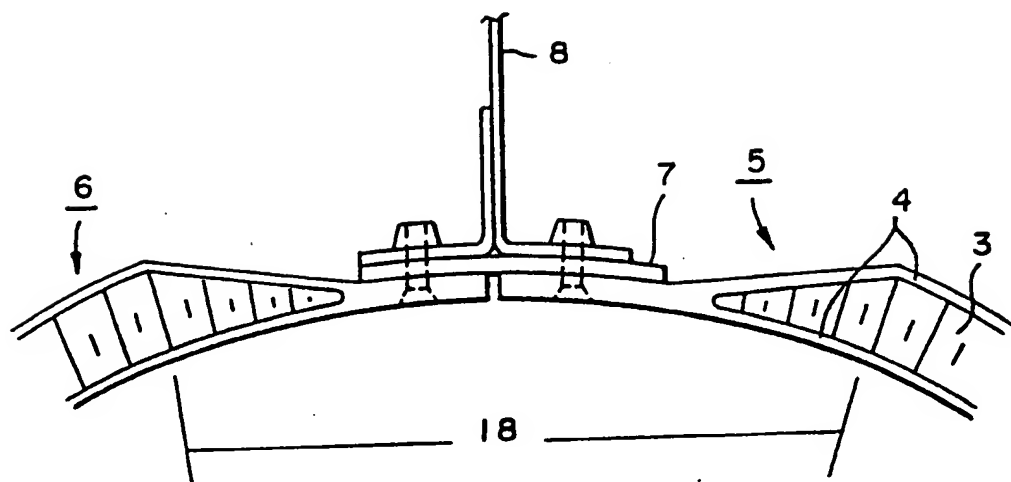


FIG. 1(b)
(PRIOR ART)

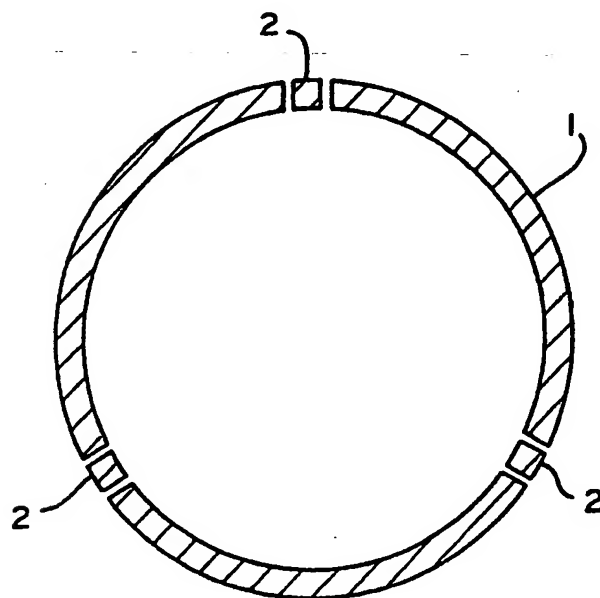


FIG. 1(a)
(PRIOR ART)

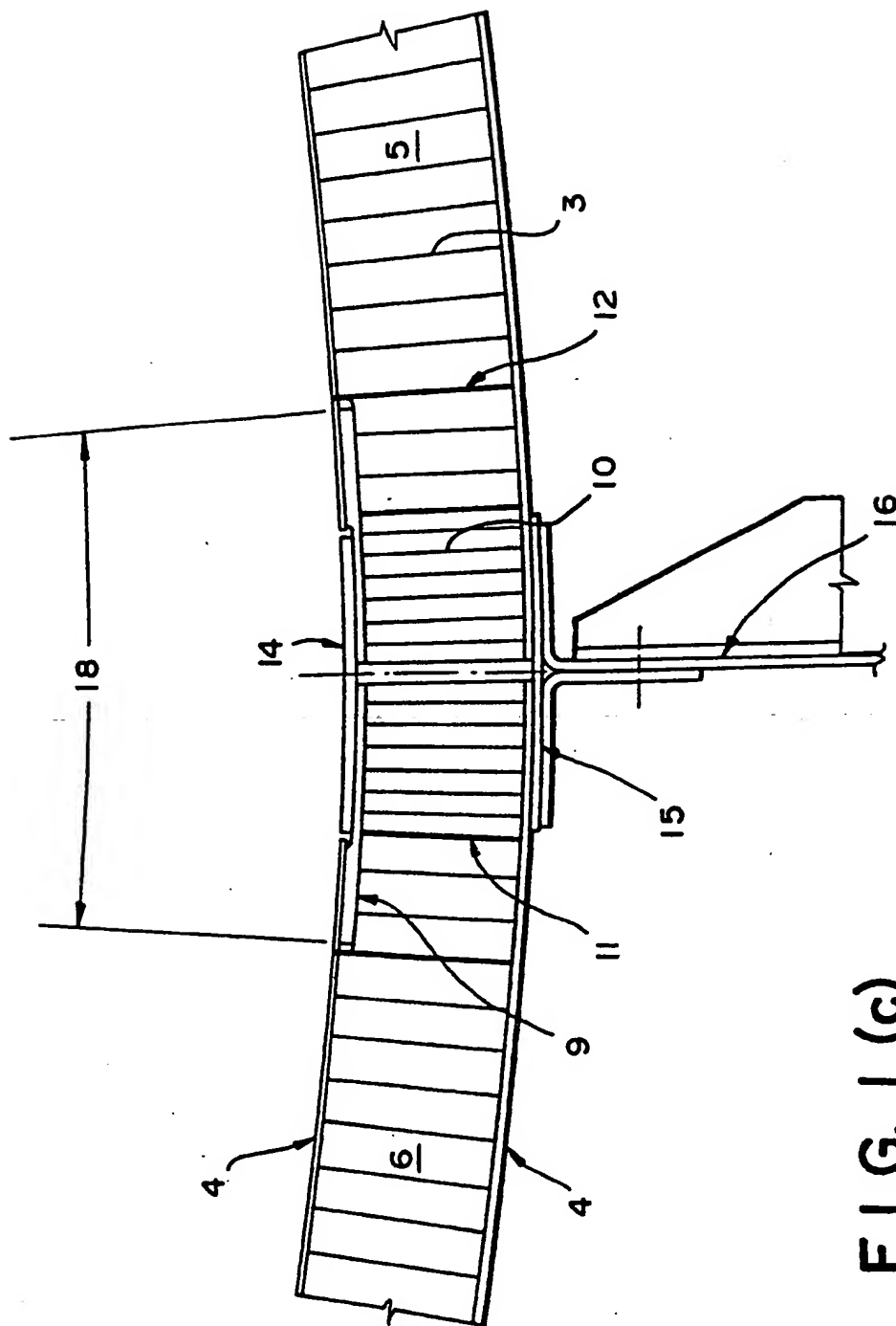


FIG. 1(c)
(PRIOR ART)

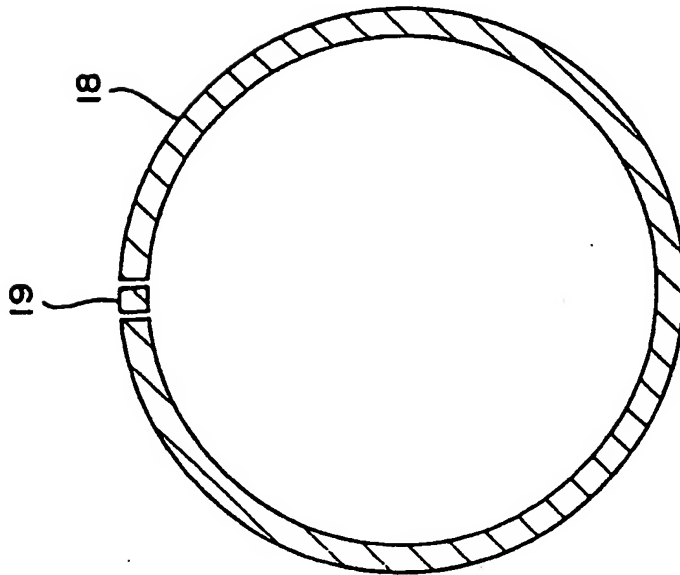


FIG. 2(a)

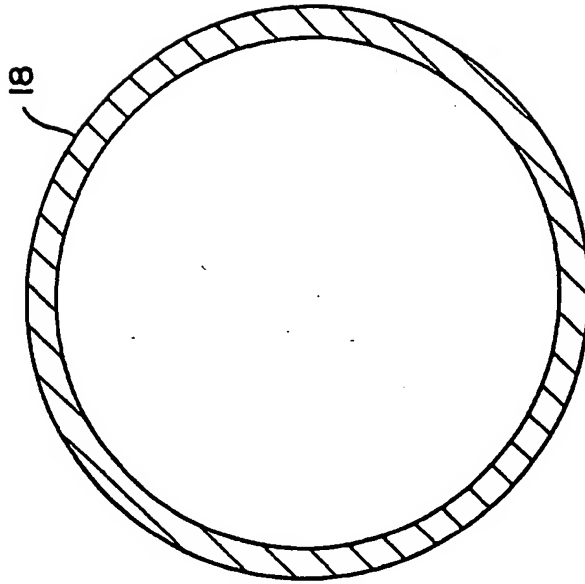


FIG. 2(b)

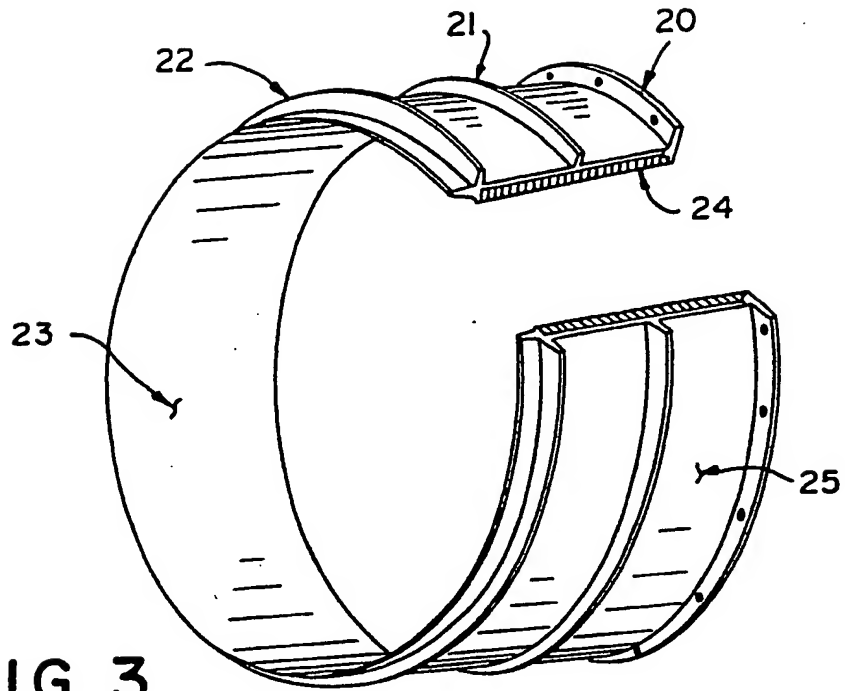


FIG. 3

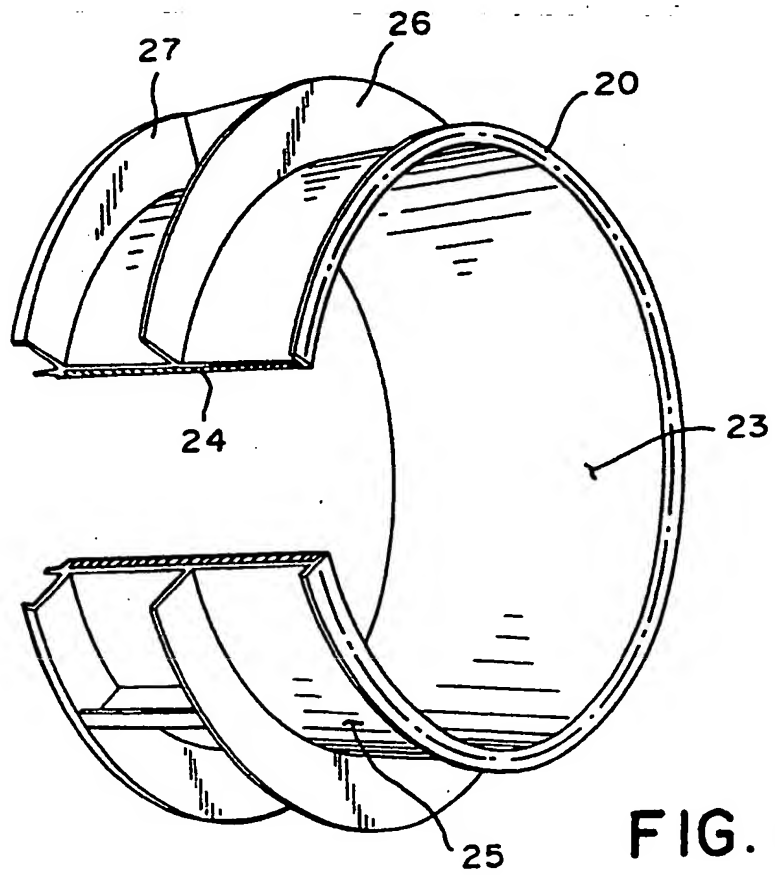


FIG. 4

FIG. 5(a)
(PRIOR ART)

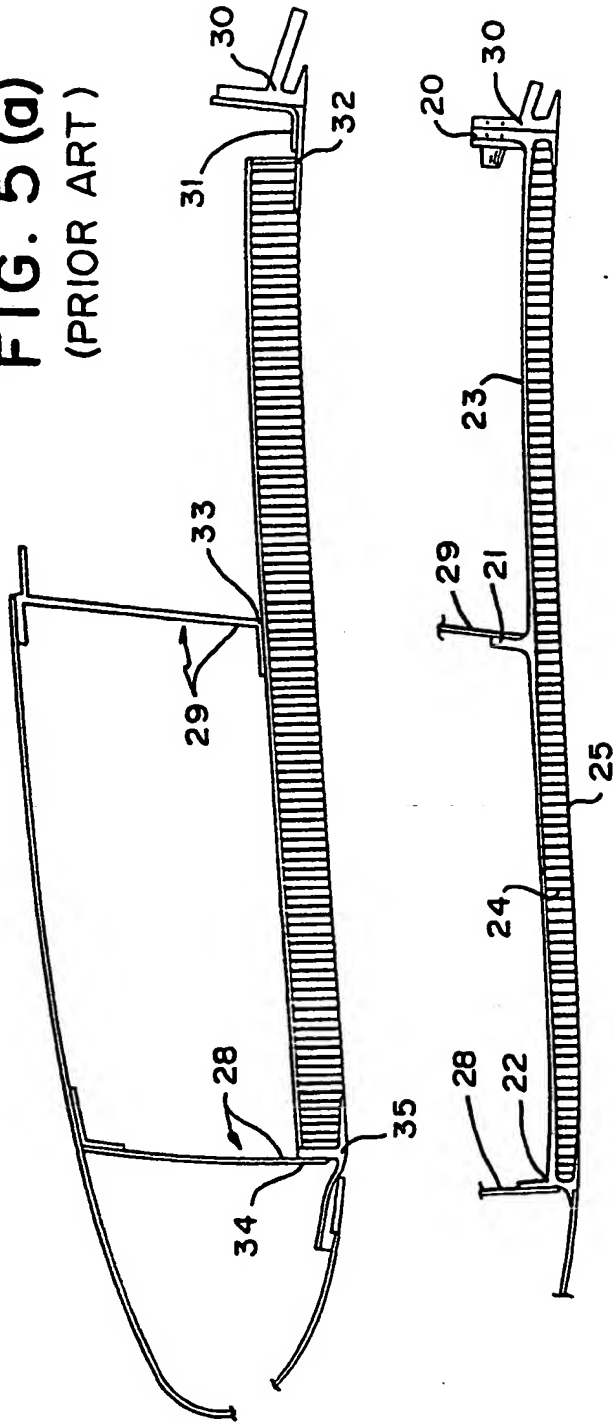


FIG. 5(b)

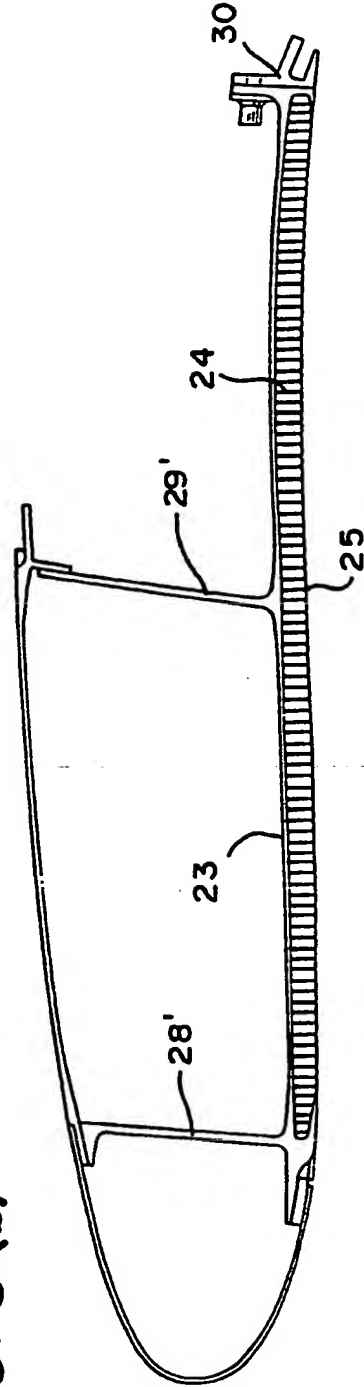
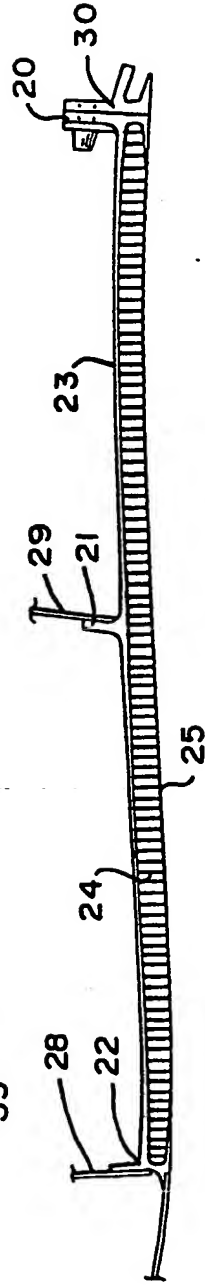


FIG. 5(c)

ONE-PIECE ENGINE INLET ACOUSTIC BARREL

This invention relates to an engine inlet acoustic barrel designed to attenuate
5 dominant frequencies generated by, for example, a jet aircraft turbo-fan engine.

Although a jet aircraft engine nacelle inlet appears to be a simple structure,
it actually embodies a sophisticated adjunct to power plant performance. While the
inner surface of the inlet must be made as smooth as possible for aerodynamic
10 reasons, acoustic considerations demand a non-continuous porous air passage surface
of a defined depth behind the air passage surface. As a result, current state-of-the-art
construction incorporates multiple cavities behind the air passage surface such as
might be created by a honeycomb core. However, the core depth required for

optimum acoustic attenuation is not necessarily equal to an optimum core depth required for the sandwich barrel structure to withstand all the aerodynamic and inertial loads to which it is subjected in service.

Current inlet acoustic barrels, including those made from advanced composite materials such as graphite epoxy cloth, and/or tape, are constructed from two or three curved segments that are fastened or spliced together to create a nearly cylindrical shape. The segments are constructed, starting from the inlet air-passage surface, of a permeable inner facesheet, a honeycomb core, and a solid non-permeable back facesheet, and are fastened together along splice lines running in the fore-aft direction. The splice lines involved in such designs are generally made of a non-non-permeable structural attachment material and have several disadvantages, among them that the splice lines decrease the total active acoustic area. In addition, the presence of splices causes the acoustic modes generated by the fan to be altered to lower order modes, which are difficult to attenuate and thus decrease the efficiency of the liner. Other disadvantages of the splice lines include an increase in the structural weight of the barrel, and stress concentrations at the splice lines.

Examples of composite acoustic jet engine liners are disclosed in U.S. Patent Nos. 5,025,888, 5,014,815, 4,969,535, 4,840,093, and in U.S. Patent Application Serial Nos. 07/611,633 and 07/670,917, each of which is incorporated herein by reference.

The barrel schematically illustrated in Figure 1(a) represents a currently existing production barrel 1 of the type disclosed in the above-mentioned patents and patent applications. Barrel 1 includes a splice 2 every 120°. The core structure 3 of barrel 1 in the area of the splice may be tapered or stepped, with facesheets 4 formed to facilitate attachment of two sections 5 and 6 using a splice strap 7 and an intracoastal support 8, as shown in Figure 1(b), which is typical of fiber reinforced composite construction. Alternatively, the core structure may simply be abruptly terminated, as shown in Figure 1(c), with attachment facilitated by a structural doubler 9, a densified core 10, structural core splices 11, and optional core splices 12, in addition to splice straps 14 and 15 and intracoastal support 16. This example of an existing barrel is more typical in metallic construction. The total area lost by the splice in both Figures 1(b) and 1(c) is indicated by arrow 18.

Thus, the conventional inlet acoustic barrels constructed from two or three (and possibly more) nearly equally sized curved structural sandwich panel segments are usually fastened together along splice lines with discrete fasteners, to create a nearly cylindrical shape. This segmental construction presumes that each of the segments, by itself, is designed to support in-plane and bending loads as a curved sandwich plate of, starting from the inlet air-passage surface, the above-mentioned perforated permeable facesheet, a core, possibly in the form of a honeycomb core, and, the solid i.e., non-perforated back facesheet.

The sandwich plates are fastened together along a splice-line running in the fore-aft direction, the construction of the panel-to-panel boundary splice line being of

necessity more robust than the interior region of the sandwich. The in-plane and bending loads that are distributed rather uniformly in the field of the curved plane must be transmitted through discretized load paths of the individual fasteners connecting panels to each other and, in some instances, to surrounding structure such as intracoastals, rings, or attachment fittings.

Metallic, as well as traditionally configured, advanced composite sandwich designs adhere to the structural philosophy that all required bending rigidity should be developed by causing the inner and outer facesheets to act as a structural sandwich in differential bending and that the core material between facesheets should support substantially all the shear loads. Under other circumstances, this usually provides a very efficient structure. However, in the case of acoustic barrels, the perforated facesheet 23 near the air passage surface, which may be covered on either side with another material such as stainless steel, woven wire, or a similar-finely porous material to enhance acoustic performance, serves a dual role. It acts as an element of a tuned Helmholtz resonator for acoustic attenuation, as well as a structural-sandwich facesheet that supports loads in differential bending.

Since the air passage facesheet must be perforated for acoustic performance, its cross-sectional area through its thickness is greatly reduced for the purpose of resisting in-plane loads due to direct stretching or differential bending. As a result, the perforated facesheet thickness must be sized to meet structural demands that may conflict with what might be optimum for maximum acoustic performance. In particular, the perforated facesheet thickness must be increased beyond that needed

just to replace the volume of material removed from the holes because of the stress concentrations around each hole. The extra thickness required also tends to reduce acoustic performance, because it increases an acoustic property of the perforate called "mass reactance" which is related to the dynamics of vibrating the slug of air contained in the perforated hole. Since acoustic performance is sensitive to the phenomenon, it would be preferable to size the facesheet thickness based on acoustic considerations without having to make concessions to structural requirements. Generally, a thinner perforated facesheet is preferred.

The preferred embodiments of the invention, on the other hand, use an alternative design philosophy that is closer to pure monocoque construction and which offers significant benefits compared to the current art. The basic feature of a one-piece monocoque is that the primary loads are supported by a single continuous structural shell. While the core and permeable facesheet supports some internal loads by virtue of strain compatibility, they can be thought of as nearly parasitic when incorporated in a monocoque or ring stiffened barrel such as described herein.

The preferred forms of the invention, which will be described in more detail below, obviate all discrete seams and splices, especially in the fore-aft direction. Some inlet constructions call for the use of a microporous air passage layer, while other noise attenuation systems may require only the use of discretely perforated air passage skins. Usually, this choice is dictated by the engine manufacturer who is familiar with the noise characteristics of the engine. In either case, the preferred forms of the invention seek to maintain uniformity of the structure and material

associated with the acoustic attenuation system in particular, and the entire structural system in general.

5 This does not mean that the facesheet porosity may not vary over the entire area in some controlled, predetermined way, or that core thicknesses and cell size must be constant everywhere. In fact, controlled variability may be desirable in certain cases. However, the presence of hardwall regions, i.e., abrupt changes from acoustically treated to acoustically untreated regions, especially fore and aft strips of untreated hardwall areas such as found in splice areas, are to be avoided whether or not the system includes some form of microporous facesheet. The presence of
10 hardwall strips (splices) alters the tones generated by the engine in currently unpredictable ways and reduces the essentially tuned liner's effectiveness to attenuate noise energy at desired frequencies.

Although the advantages of composite material technology in reducing the number of parts in aircraft structures have long been recognized, for example as
15 described in U.S. Patent No. 4,826,106, the acoustic advantages of such a design, in particular as applied to an aircraft engine nacelle, have not been appreciated. Patent No. 4,826,106, for example, proposes the formation of fittings in a jet engine cowling assembly as a one-piece structure. In this patent, however, the term "one-piece" refers to the formation of various parts of the cowling using "judiciously placed
20 graphite/epoxy unidirectional tape layers" to form integrated, seamless structures, but not to the elimination of fore-to-aft splices.

It is a principal objective of the invention in preferred embodiments at least to provide an improved acoustic liner jet engine inlet barrel formed from a perforated permeable inner facesheet, a core structure, and a solid facesheet, and having at least the following advantages: an increase in total active acoustic area, unaltered acoustic modal content, reduced structural weight, and reduced stress concentrations at joint connections by eliminating the joints entirely.

It is a second principal objective of the invention in preferred embodiments at least to provide a method of making an acoustic liner jet engine barrel formed from a perforated permeable inner facesheet, a honeycomb core structure, and a solid facesheet, the resulting inlet barrel having an increased total active acoustic area, unaltered acoustic modal content, reduced structural weight, and elimination of stress concentration at joint connections.

From a first aspect, the invention provides an engine inlet acoustic barrel substantially cylindrical in shape and having a forward end and an aft end, characterised by, from an air passage side outward: a one-piece inner facesheet; a one-piece core structure; and a one-piece non-porous back facesheet, wherein said inner and back facesheets and said core structure have at most one splice extending from said forward end to said aft end.

From a second aspect, the invention provides a method of making an engine inlet acoustic barrel, characterised by the steps of: (a) forming a substantially cylindrical one-piece non-porous back facesheet having at most one splice; (b) forming a substantially cylindrical one-piece core structure having at

most one splice; and (c) forming a substantially cylindrical one-piece inner
facesheet having at most one splice.

In preferred embodiments, the invention provides a one-piece composite
5 acoustic barrel having a perforated facesheet facing an interior of the barrel, a
core structure conventionally in the form of a honeycomb core, and a non-
perforated back facesheet, each of which is formed in a one-piece configuration
such that no splice at all or at most only a single narrow fore-to-aft splice is
formed in the finished product. No-splice embodiments of the invention are
10 formed by overlapping the constituent materials which form the respective
facesheet layers, and by joining respective ends of the core structure such that
no gap or blockage exists at the joint.

The inventive method is accomplished, in one preferred embodiment of the invention, by wrapping a continuous piece of graphite/epoxy cloth around a core form at least 360°, so that ends of the cloth are located a substantial distance apart on the form, and then curing the graphite/epoxy material to form a facesheet structure. The core structure, preferably a honeycomb core, is formed without a splice by, for example, pushing ends of the core structure together, with no glue or mechanical connections, until the core forms an integral unit, after which the completed core within the facesheet, and the two layers are glued together by reticulation. The remaining non-permeable facesheet layer may also be pre-formed and secured by adhesive bonding to the core, or may be added to the structure by co-curing with the core, depending on the viscosity of the facesheet material.

In an especially advantageous embodiment of the invention, the non-perforated backing facesheet as shown by items 20, 21, 22, 26 and 27 is built up to form structural components of the inlet barrel as shown in Figures 3 and 4 which would ordinarily be provided in the form of separate detail parts, thus reducing the total weight of the structure.

The purpose of the invention, exemplified by the preferred embodiments, is to minimize to the greatest extent possible any non-uniformity or discontinuities in the acoustic and structural aspects of the perforated and/or microporous facesheet on the side that the sound waves infringe upon as well as to maintain continuity of the cellular correlator and the non-porous/non-perforated backface sheet in the circumferential direction. This construction serves 1) to preserve the purity of the

acoustic modes generated by the engine allowing for better noise attenuation by the essentially tuned acoustic impedance inherent in the fixed geometry and porosity facesheet, core depths, etc. 2) to increase the total active acoustic area, and 3) to improve the structural performance of the inlet barrel.

Some preferred embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings in which:

5

Figure 1(a) is a schematic cross-sectional end view of a conventional acoustic liner inlet barrel having a splice every 120° .

Figures 1(b) and 1(c) are enlarged cross-sectional views of typical constructions of the barrel of Figure 1(a) in the area of one of the splices.

10

Figure 2(a) is a schematic cross-sectional end view of a one-piece single splice acoustic liner inlet barrel constructed in accordance with the principles of a first preferred embodiment of the invention.

15

Figure 2(b) is a schematic cross-sectional end view of a one-piece spliceless acoustic liner inlet barrel constructed in accordance with the principles of a second preferred embodiment of the invention.

Figure 3 is a partially cut-away perspective view a first version of a unitized barrel assembly embodying the principles illustrated in Figures 2(a) and 2(b).

Figure 4 is a partially cut-away perspective view of a variation of the unitized barrel assembly of Figure 3.

Figure 5(a) is a cross-sectional side view of a conventional jet engine nacelle structure with a state-of-the-art acoustic liner.


5 Figure 5(b) is a cross-sectional side view of the barrel assembly of Figure 3.

Figure 5(c) is a cross-sectional side view of the barrel assembly of Figure 4.

In accordance with preferred embodiments of the invention, an acoustic liner inlet barrel is formed as one continuous piece when viewed in cross-section facing the longitudinal direction of the barrel, rather than three pieces with splices as shown in Figures 1(a), 1(b), and 1(c). This one-piece acoustic liner inlet barrel design is schematically depicted in Figures 2(a) and 2(b). Essentially, the liner inlet barrel shown in Figure 2(a) and 2(b) is formed by manufacturing a continuous one-piece liner and either splicing ends of the liner together, at splice 19 as shown in Figure 2(a), or using a variety of techniques which result in a finished product which has no splice at all, as shown in Figure 2(b).

The one-piece liner 18 of Figure 2(a) is substantially cylindrical and includes, as illustrated in greater detail in Figures 3 and 4, a perforate and/or microporous facesheet 23, a honeycomb core 24 and a solid backing facesheet 25 constructed in

a conventional manner except that the structure is continuous in the circumferential direction over an angle of 360°. The splice area 19 of Figure 2(a) is formed in such a manner that the resulting splice is as narrow as possible so that it approaches the limit of no splice as shown in Figure 2(b).

5 The preferred method of making the single-splice barrel differs from the method taught in Patent No. 4,826,106 in that it is for an engine inlet barrel rather than an aircraft engine translating aft cowling, and in that instead of forming sections of less than 180° each, the barrel is formed in one piece which extends over an angle of 360°. While the materials may be the same as disclosed in Patent No. 4,826,106,
10 other suitable composite or metallic materials will occur to those skilled in the art and are intended to be included within the scope of the invention. 

 In practice, construction of embodiments that do not require inclusion of a separate microporous layer will consist of, from the inside out, the perforated laminate 23, a layer of glue (not shown), the honeycomb core 24, a layer of glue (not
15 shown), and the nonporous, continuous, backing facesheet 25. The layers of glue on the inside and outside of the core may be brought to the assembly as discrete layers, or, under controlled conditions, the bond between core and either facesheet can be made with the resin from the contiguous laminates.

 If a microporous facesheet is required, it may be incorporated either as the air
20 passage (first) layer or just beneath the air passage perforate. In either case, if the microporous layer (which may be made for example of a woven mesh and which is

used to obtain desired acoustic properties of the liner) is only available in sheet form, its ends must be joined on the circumference in a manner that results in a discontinuity of material physical and mechanical properties, i.e., a splice. This is a concession to practicality that may have to be accepted for reasons of cost, but there are also methods of weaving cylindrical geometries that may be employed, at additional cost, to obviate the need for a splice even in this layer.

The perforate facesheet can be a fiber reinforced laminate such as graphite/epoxy, graphite/bismaleimide, glass/epoxy or other such material that might occur to those skilled in the art. The holes may be molded into the laminate in a separate curing process or molded into the facesheet during a co-curing/bonding operation that includes the core and/or the solid back facesheet. One form of the construction may use a metallic porous facesheet made circumferentially continuous by some form of welding and subsequently formed to near-cylindrical shapes by magnaforming or other similar processes. In order to eliminate the facesheet seams, the facesheets may, for example, be formed by wrapping the facesheet material around a form to an angle of greater than 360° before curing. The core structure may be formed by applying pressure to ends of a honeycomb to thereby push them together until no seam is apparent.

In the preferred embodiment of the invention, shown in Figures 3 and 5(b), integral fittings are provided by weaving or braiding graphite yarn into a preform, for example in the manner taught in Patent No. 4,826,106. These preforms are then impregnated with an epoxy or other resin so that they can easily and quickly be added

to the wet barrel assembly and cured simultaneously with the acoustic sandwich to create a non-splice continuous structure without the need for separate discrete fastener attachment. This results in a lighter weight, more durable structure. These include an integral engine mounting flange 20 to which engine frame 30 is attached at an aft end of the barrel, a firewall ring frame attachment flange 21, and an L.E. ring frame attachment flange 22 at the forward end. Figures 3 and 5(b) also show the perforated facesheet 25, honeycomb core 24, and non-porous facesheet 23. The barrel structure of Figures 3 and 5(b) may either have a single splice or no splice. A portion of the structure has been cut away to reveal the core 24.

10 In another preferred embodiment, it is possible to add the firewall ring frame and the L.E. ring frame by building up the attachment flanges, as shown in Figures 4 and 5(c), in order to replace the conventional ring structures 28 and 29 shown in Figures 5(a) and 5(b) by a firewall ring 29' and an L.E. ring 28'. As a result, even with an increased acoustic area, the weight of the barrel including anti-ice installation is actually reduced, as is the cost, relative to the acoustic inlet barrel shown in Figure 15 5(a), which is a state-of-the-art construction with non-integral fittings 31 to 35.

20 Having thus described in detail specific preferred embodiments of the invention, it is nevertheless intended that the invention not be limited by the above description, but rather that it be interpreted solely in accordance with the appended claims.

CLAIMS:

1. An engine inlet acoustic barrel substantially cylindrical in shape and having a forward end and an aft end, characterised by, from an air passage side
5 outward:
a one-piece inner facesheet;
a one-piece core structure; and
a one-piece non-porous back facesheet, wherein said inner and back
facesheets and said core structure have at most one splice extending from said
10 forward end to said aft end.
2. An engine inlet acoustic barrel as claimed in claim 1, characterised in
that said inner facesheet is porous or microporous.
- 15 3. An engine inlet acoustic barrel as claimed in claim 1 or claim 2, further
characterised by a microporous layer positioned on the air passage side of the
inner facesheet, said microporous screen having at most one splice.
4. An engine inlet acoustic barrel as claimed in any preceding claim,
20 characterised in that said core structure and/or said non-porous back facesheet
is spliceless.
5. An engine inlet acoustic barrel as claimed in any preceding claim,
characterised in that said inner and back facesheets are graphite/epoxy
25 facesheets and said core structure is a honeycomb type core.

6. An engine inlet acoustic barrel as claimed in any preceding claim,
characterised in that said non-porous back facesheet includes an integral engine
mounting flange and/or an integral firewall ring attachment flange and/or an
integral L.E. ring attachment flange and/or an integral firewall ring and/or an
5 integral L.E. ring.

7. A method of making an engine inlet acoustic barrel, characterised by the
steps of:

- (a) forming a substantially cylindrical one-piece non-porous back
10 facesheet having at most one splice;
- (b) forming a substantially cylindrical one-piece core structure having at
most one splice; and
- (c) forming a substantially cylindrical one-piece inner facesheet having at
most one splice.

15

8. A method as claimed in claim 7, characterised in that said facesheets are
formed by wrapping graphite/epoxy cloth around a form to an angle of greater
than 360° before curing.

20

9. A method as claimed in claim 7 or 8, characterised in that said core
structure is formed by applying pressure to ends of a honeycomb structure to
push them together until no seam is apparent.

10. A method as claimed in any of claims 7, 8 or 9, further characterised by
25 the step of inserting the core structure into the non-porous back facesheet and

gluing the core structure and back facesheet together and/or the step of inserting the porous inner facesheet into the core structure and gluing the porous inner facesheet and core structure together.

- 5 11. A method as claimed in any of claims 7 to 10, further characterised by the step of co-curing the facesheets and core structure.

- 10 12. A method as claimed in any of claims 7 to 11, characterised in that step (a) comprises the step of forming integral engine mount, firewall ring, and L.E. ring attachment flanges or integral firewall and L.E. rings by weaving or braiding graphite yarns into a graphite pre-form and then impregnating with resin for inclusion in an integral co-cured assembly.

- 15 13. An engine inlet acoustic barrel substantially as hereinbefore described with reference to the accompanying drawings.

14. A method of making an engine inlet acoustic barrel substantially as hereinbefore described with reference to the accompanying drawings.

Patents Act 1977 miner's report to the Comptroller under Section 17 (The Search report)	Application number GB 9324728.6
Relevant Technical Fields (i) UK Cl (Ed.M) F1G (GFB, GFX) F1J (JCC) (ii) Int Cl (Ed.5) F02C (7/00, 7/04, 7/045) Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASE: WPI	Search Examiner C B VOSPER
	Date of completion of Search 21 JANUARY 1994
	Documents considered relevant following a search in respect of Claims :- 1 TO 6

Categories of documents

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| X: Document indicating lack of novelty or of inventive step. | P: Document published on or after the declared priority date but before the filing date of the present application. |
| Y: Document indicating lack of inventive step if combined with one or more other documents of the same category. | E: Patent document published on or after, but with priority date earlier than, the filing date of the present application. |
| A: Document indicating technological background and/or state of the art. | &: Member of the same patent family; corresponding document. |

Category	Identity of document and relevant passages	Relevant to claim(s)
Y	GB 2247712 A (SHORT) whole document - shows sheet/core construction per se	1,2,5
Y	GB 2223448 A (SHORT) whole document - shows sheet/core construction per se	1,2,3
Y	GB 2076049 A (ROLLS-) Figure 1, page 1 lines 39 to 47, - shows sheet/core construction per se	1,2,3
Y	GB 2038410 A (ROLLS-) Figure 1 - shows sheet/core construction per se	1,2
Y	GB 1456302 (GENERAL) Figure 3 - shows one-piece accoustic barrel	1 to 3 and 5
Y	GB 1236854 (GENERAL) Figure 2 and 3, page 2 lines 29 et seq - shows one piece (hoop) accoustic barrel	1 to 3 and 5
Y	US 4759513 (QUIET/BIRBRAGHER) whole document - shows sheet/core construction per se	1,2,3 and 5
X:Y	US 4600619 (BOEING/CHEE) whole document	1,2,4:3,5
Y	US 4421201 (BOEING/NELSON) whole document - shows sheet/core construction per se	1,2

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Continuation page

Category	Identity of document and relevant passages		Relevant to claim(s)
Y	US 4235303	(BOEING/DHOORE) whole document - shows sheet/core construction per se	1,2
X:Y	US 4122672	(ROLLS/LOWRIE) Figures 2, 3a column 2 line 52 et seq	1,2,4:3,5
Y	US 4023644	(BOEING/COWAN) column 4 lines 3 to 11 - shows one-piece barrel	1 to 3 and 5